Chapter 2
Definitions and Concepts

2-1. Overview

This chapter gives an integrated overview of major concepts and processes detailed in the chapters that follow. Appendix C is a glossary that can be consulted to review unfamiliar terminology.

2-2. Nearshore Region

a. Processes. The littoral zone is the dynamic interface between the ocean and the land. Bounded on one side by the landward limit of the beach and extending seaward to just beyond the zone of wave breaking, it is the region where wave energy dissipates over a distance of tens to hundreds of meters. Beaches are molded into characteristic forms according to various governing parameters, including rates of wave energy dissipation and momentum transfer, and sediment permeability and fall velocity. A dynamic balance is established between processes and morphology in which the beach, waves, and currents interact. Natural variability in littoral processes, such as in wave height, period, and direction, or the rate that littoral material is supplied to a region, are responsible for beach changes. Modifications to the system such as changing wave conditions, introduction of engineering structures, and altered quantity or type of sediment all cause the dynamic balance to readjust. Rapid and undesired beach changes have been caused by some coastal engineering works. A methodology is provided herein for analyzing the effects of proposed engineering activities on the littoral zone in order to achieve the most desirable solution within project objectives.

b. Littoral materials. The geology of the coast and of the source area of littoral materials ultimately determines the prevalent shape of the shore at a specific locality. Rocky shores are exposed where there is no supply of beach material or the transport out of the region exceeds the sediment input. Gravel beaches, also known as shingle beaches, exist in areas where the only material supplied is coarse, or may develop as a lag deposit in the presence of vigorous wave activity. Some shores are composed of mud and receive such a small amount of incident wave energy that they are termed zero-energy coastlines. However, the focus of this manual is on sandy beaches, those composed of materials in the approximate range of 0.15 mm to 2.0 mm in diameter. About a third of the exposed shorelines of the United States, excluding Alaska, are comprised of unconsolidated materials, and these beaches typically receive the greatest commercial, private, and recreational usage. Primary sources of beach sand are the erosion of upland areas and bluffs and biogenic production. Under some conditions sand may move onshore from submerged deposits. Calcium carbonate sands produced in shallow tropical seas are often moved onshore to create beaches in this manner.

c. Morphologic features. In cross-section the sandy beach profile can be divided into zones according to morphologic features, as shown in Figure 2-1. Beaches are often backed by dunes. Seaward of the dunes is the littoral zone, consisting of the backshore which is rarely submerged; the foreshore, which extends from the limit of uprush of waves at high tide to the backrush of waves at low tide; and the inshore, where energy of spilling and plunging breakers is dissipated. The offshore is separated from the inshore by the location of wave breaking and is included in the littoral zone to the extent that significant littoral processes occur. The backshore is a relatively flat area or consists of flat areas separated by beach scarps. The berm crest separates the berm from the more steeply sloping foreshore.

d. Wave processes. In terms of wave processes, the littoral zone is divided into the offshore and nearshore zones (Figure 2-2). Within the nearshore zone, waves become unstable and begin to break in the breaker zone. Broken waves propagate as bores in the surf zone. The limits of water oscillation on the beach face define the swash zone.

e. Beach profiles. A sandy beach tends toward an equilibrium profile for swell waves. This equilibrium profile, called a summer or swell profile, has been the subject of much field and laboratory investigation and occurs when the depth increases exponentially with distance from shore. Under certain combinations of wave height, period, and sand fall velocity, the profile develops a shore-parallel bar at the location of wave breaking. A trough just shoreward of the bar or under the plunge point of the breaker is also common. If waves reform after initial breaking to break a second time, the nearshore zone may contain multiple bar-trough systems. This profile is called the storm profile or winter profile. The size and location of the bar and trough are related to wave height and period. As a longshore bar grows, its location shifts, as does the wave break point. Material forming the bar is removed

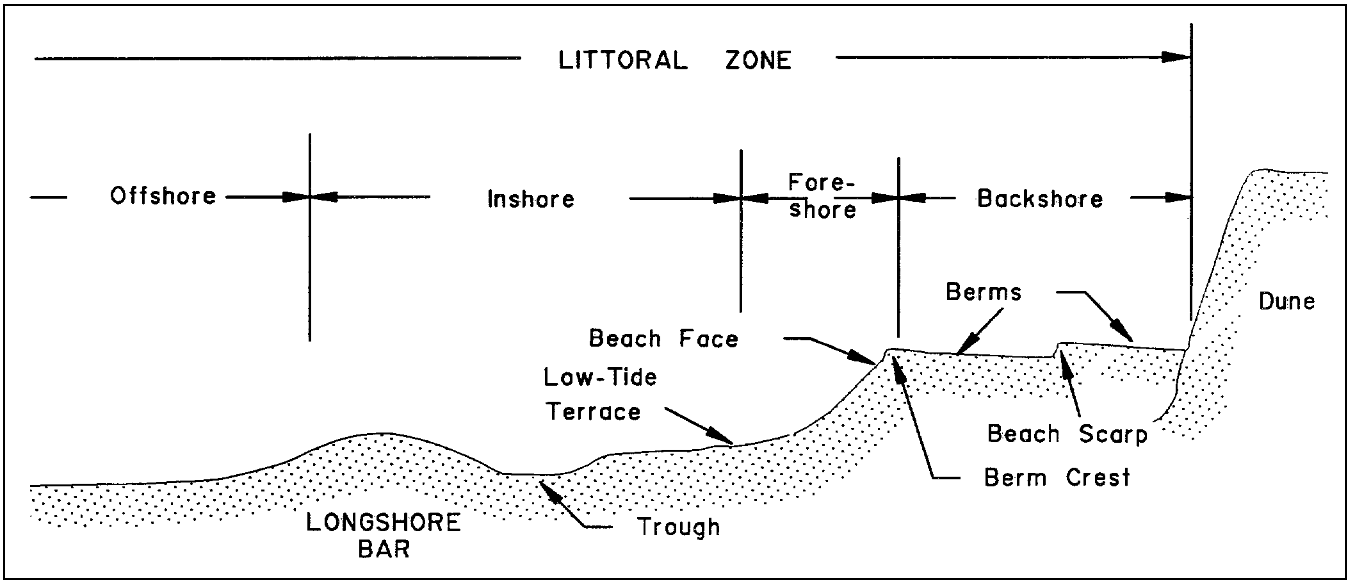

Figure 2-1. Beach profile terminology

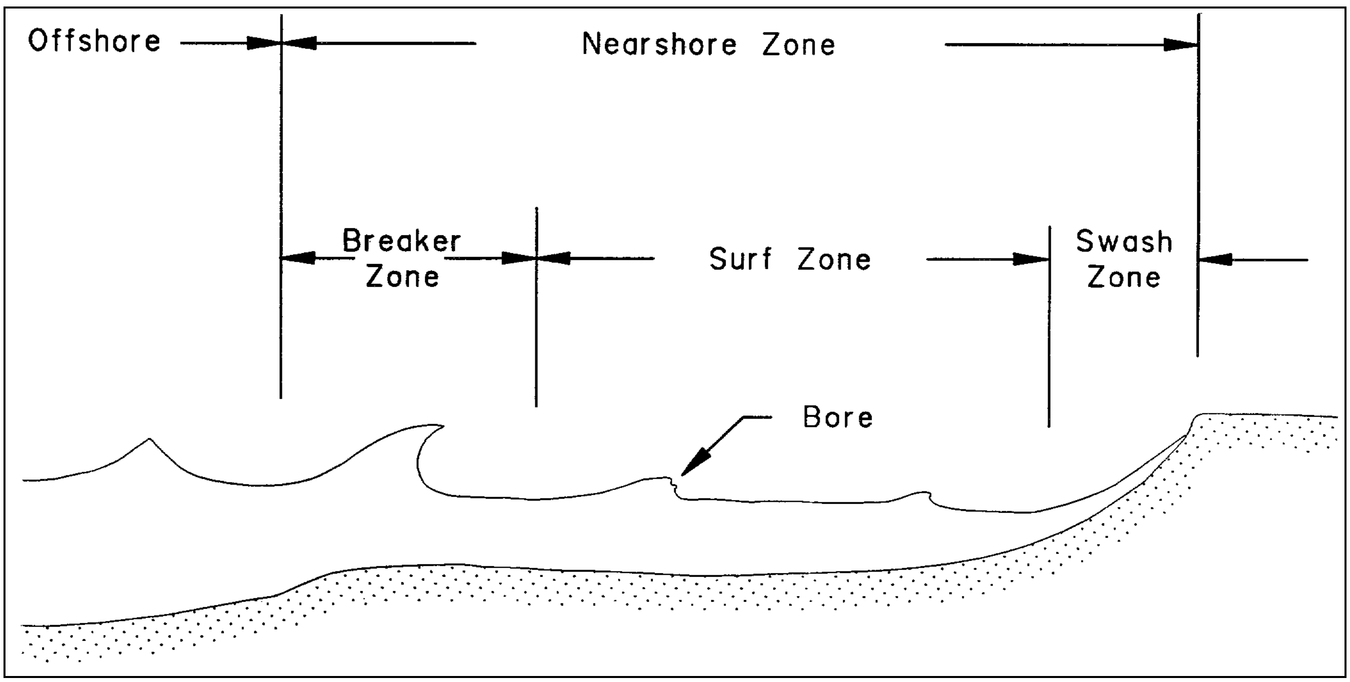

Figure 2-2. Nearshore wave processes terminology

from the beach face and berm. Significant longshore transport takes place on the longshore bar. Sand from the bar is returned to the upper profile with the return of swell waves.

f. Geomorphic features. Much of the low-lying sandy coastline in the United States is associated with barrier islands. Barrier islands are shore-parallel, linear features. They have lagoons and back bays and are interrupted by inlets or passes. The ocean beaches have a mild slope which causes waves to break offshore, dissipating their energy over a wide surf zone. Another type of linear feature is a spit, which usually grows in the direction of longshore transport from a more stable land form.

g. Cuspate features. A variety of cuspate features are observed in the littoral zone, including beach cusps, crescentic bars, and cuspate forelands. Beach cusps are an alongshore series of horns separated by embayments in the swash zone. Beach cusps point seaward and their spacings may range from 1 to 60 meters. Crescentic bars lie seaward of the low-water position with the concave sides facing the beach and are spaced at 100 meters (m) to 2000 meters. Cuspate forelands are found in elongate water bodies and on outer coasts facing crescentic bars. A cell circulation pattern with a single rip current can develop within these cuspate features (Figure 2-3a). At other times several rip currents may be present within the outer crescentic bar, cresting a segmented linear inner bar (Figure 2-3b). The inner bars and shoals align with approaching wave crests. If waves change to arrive at an oblique angle to the beach, the shoals, rip currents, and troughs also rotate and may form sand waves or transverse bars (Figure 2-4).

h. Plan-view response. If alongshore-moving material encounters a relatively impermeable littoral barrier, an accumulation forms, called a fillet. The shoreline tends to become oriented with incident wave crests to establish a uniform longshore transport rate. An embayment downdrift of a promontory that partially blocks transport develops a spiral shape in response to the wave refraction and diffraction at the promontory. Beaches completely confined by littoral barriers and of relatively short along-coast extent are termed pocket beaches.

i. Wave parameters. Waves are the single most important forcing mechanism in nearshore physical processes. Waves in the littoral zone are very complex and a number of theories involving different levels of approximation have been developed. The most commonly used is linear wave theory, which characterizes a single wave by its height, length, and period. Wave height is the vertical distance between crest and trough, and amplitude is that between the still-water level and the crest or trough. Wavelength of a single wave is the horizontal distance between adjacent wave forms, often taken as the point of zero downcrossing (where the water surface intersects the still-water line). Wave period is the length of time for adjacent wave forms to pass a fixed point. Wave frequency is the inverse of period. Linear waves are symmetrical about the still-water level, and the wave height is assumed small with respect to the length. Neither of these assumptions is valid in the littoral zone. Nevertheless, many quantities derived using linear wave theory in shallow water are useful in nearshore process calculations. In linear wave theory, wavelength can be computed from knowledge of the wave period and water depth. Thus the true

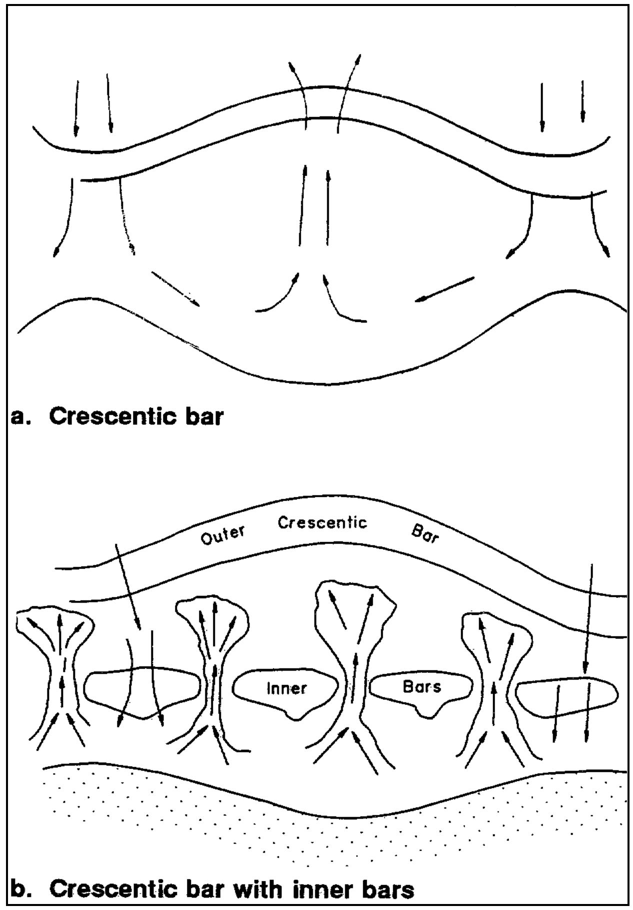

Figure 2-3. Cell circulation patterns due to various morphologies

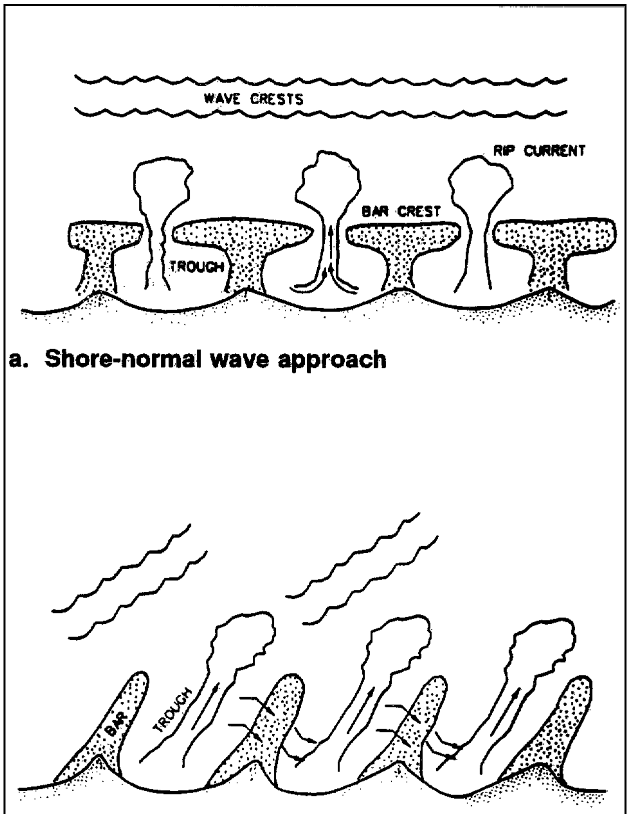

Figure 2-4. Inner bars and troughs as a function of wave direction

fundamental variables are wave height, wave period, and water depth.

2-3. Littoral Zone Dynamics

Water circulation in the littoral zone results from a combination of oceanographic currents, tidal currents, wave-induced currents, and wind-induced currents. Sediment will move in the direction of the current, and circulation currents caused by breaking waves are typically the most important to littoral transport. Therefore, the discussion of circulation is limited to that generated by waves. When waves propagate into the surf zone and break, their momentum is transferred in part to changing the water level and generation of currents. The shore-normal gradient in the momentum flux is balanced by a displacement of the mean free surface, termed wave setup and setdown.

a. Longshore current. If waves break at an oblique angle to the shoreline, a longshore current is generated by the gradient of momentum flux in the surf zone. A gradient in breaker height may be created by a particular wave transformation pattern or by wave blocking by some structure or land mass. The result is a differential setup which drives a current in the direction of the lower wave height. The longshore current is primarily confined to the surf zone with a maximum value near the midsurf position.

b. Sand transport. Sand transport in the nearshore may be as bed load or suspended load. The relative importance of these modes varies depending on the sediment and wave conditions. Suspended load is that part maintained above the bed by fluid turbulence. Bed load is that part maintained in a dispersive state by grain-to-grain collisions. The longshore sand transport rate is computed using an empirical relationship between volumetric transport rate and the longshore component of wave energy flux evaluated at the breaker zone. Wave energy flux is calculated in terms of wave height and period. Transport rates are expressed as cubic meters or cubic yards per day or year.

2-4. Variability in Sediment Transport

Sediment transport rates often vary significantly at a location. This variation can be on a time scale of days, individual storms, seasons, years, or decades. Storms cause variability in beach width by modifying the nearshore profile and by transporting sand from the beach or dunes to the offshore. Depending on their track, storms may also generate currents which reverse the direction of longshore transport. Longshore transport magnitude and direction may vary along the coastline because of wave transformations or a change in local shoreline angle. At a particular coastal location, transport may be to the right (by convention, the orientation is looking seaward) during one part of the year and to the left during the remainder of the year. Annual net transport is the difference between the left and right transports. Gross transport is the sum of the magnitudes of left and right transports. A longshore gradient in net longshore transport rate results in a loss or gain of sand volume in the section of coast. A change in sand volume over a period of many years is reflected in a change of average berm width, since the shape of the beach profile tends to remain constant.

2-5. Sediment Budget

A sediment budget is a mass balance of sediment for a specified reach of shoreline. It is an accounting of sediment movement into and out of the reach and the resulting gains or losses in sediment volume. If there is a gradient in the rates of sediment transport entering or leaving the cell, then the volumes of sand entering and leaving the reach do not balance and there must be a change in sand volume within the reach. Sediment can also be lost or gained from the offshore and backshore, such as gains from river discharges and losses from dredge material placement out of the littoral zone. The time interval of the budget analysis is arbitrary. However, most budget analyses are performed to understand the long-term change of the shoreline. For these studies the time interval must be long enough to average out seasonal variations.